TECHNICAL PROGRAM: BAA number 15-001

Supplementary measurements in the Beaufort/Chukchi 2015 MIZ

Proposed period of performance: **2 year, FY2015 – FY2016**

Year 1 Annual Report

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LONG-TERM GOALS

The extremely successful 2014 field season of the *Emerging Dynamics Of The Marginal Ice Zone DRI* allowed us to autonomously examine one year's evolution of the lower atmosphere, sea ice and upper-ocean within the Beaufort/ Chukchi Sea marginal ice zone (MIZ). It is both advantageous and scientifically valid to continue this monitoring effort and put the 2014 measurements in the context of subsequent years' MIZ evolution. This programme of research does exactly this.

This 'materials only' program builds on the expertise of the entire MIZ team, in particular the work of Martin Doble, Phil Hwang, Craig Lee, Ted Maksym, Jim Thomson, and Peter Wadhams. All data gathered is available, via the web, in near real time.

OBJECTIVES

The objective is to build up a time-series of key parameters in order to investigate whether waves travelling into the pack from the open ocean play a significant role in sea ice breakup and subsequent melt of sea ice in the Beaufort/ Chukchi Sea region, or whether a 2014 situation – in which waves were only experienced late in the melt season i.e. when the ice had already largely rotted in-situ – is repeated.

A full-scale deployment, as we performed in 2014, is presently financially and logistically out of the question, a minimum effort - using in-kind logistics offered again by the South Korean icebreaker *Araon* - is scientifically very valuable. For this smaller effort we prioritised the acquisition of simultaneous data on sea ice mass balance, the wave field, and key meteorological parameters. To put these measurements in a larger spatial context satellite data was also requested. Our minimalistic array included:

- 3 x wavebuoys (WBs),
- 3 x ice mass-balance buoy (IMBs) and
- 1 x automatic weather station (AWS).

As with the 2014 effort the IMBs and WBs were to be spaced at approximately one degree of latitude (100 km), from the ice edge north. Each WB is accompanied by an IMB to track the evolution of the ice thickness and provide a photographic record of the ice conditions surrounding the IMB. The automatic weather station (AWS), co-located with the northern most WB and IMB, will provide valuable wind, air temperature, and incoming radiation data to understand the observed drift and ice thickness changes.

Annual Objectives

Year 1 objectives:

- Build of 3 x WB, 3 x IMB and 1 x AWS
  - Result: COMPLETED
- Test and QC 3 x WB, 3 x IMB and 1 x AWS before shipping
  - Result: COMPLETED
- Transport 3 x WB, 3 x IMB and 1 x AWS to Nome Alaska for pick up by *Araon*.
  - Result: COMPLETED
- Deploy 3 x WB, 3 x IMB and 1 x AWS
  - Result: SEMI-COMPLETED, ON-GOING
- Real-time access to all data via dedicated website
  - Result: COMPLETED
- Quality control and finalisation of resultant datasets
  - Result: ON-GOING

APPROACH

This was a very tight design, build and deployment programme, essentially a six week window to build seven systems from scratch (3 x WBs, 3 x IMBs and 1 x AWS). Funding was approved in the latter half of May, and shipping from Europe to Alaska needed to be performed by mid-July. There was no room for slippage. Our internal review process (including lead times) suggested that it was indeed doable, but extremely tight. As with all design and fabrication projects BAS has rigorous procedures in place to ensure our quality control is not compromised, even under tight deadlines.

WORK COMPLETED

During the intense 6-week build and testing phase we had numerous internal meetings at BAS, as well as regular communications with contractors and suppliers to ensure everything was on track. By doing so we were able to ensure that all systems were built to a high standard, successfully passed our testing procedures, and the logistics were in place for the pick-up and delivery to Nome, Alaska. Hand-in-hand with this process was the additional work involved in ensuring the communication system between BAS and the buoys worked correctly and that resultant data was available to all interested parties in near real time. We can summarise this year's achievements into two areas:

1. **Buoy build:** This work covers seven buoy systems. The Wavebuoys (WBs) and automatic weather stations (AWS) are identical to those built during the MIZ 2014 no additional development work was needed. The ice mass balance buoy (IMB) was a full redesign and update. It now uses high-precision temperature sensors (0.0078C), a different communication protocol, and a dedicated camera unit. Below is a summary of the parameters and data transmission frequency:

Wavebuoy:

- 1 sec X, Y, Z acceleration, roll, heave, magnetometer
- Hourly GPS
- 6 hr photograph
- Air pressure
- Hourly Engineering data

Automatic Weather Station

- Hourly GPS
- Hourly Air temperature
- Hourly Humidity
- Hourly Air pressure
- Hourly Wind speed and direction
- Hourly Solar radiation
- Hourly Rotation (compass)
- Engineering data

Ice Mass Balance buoy

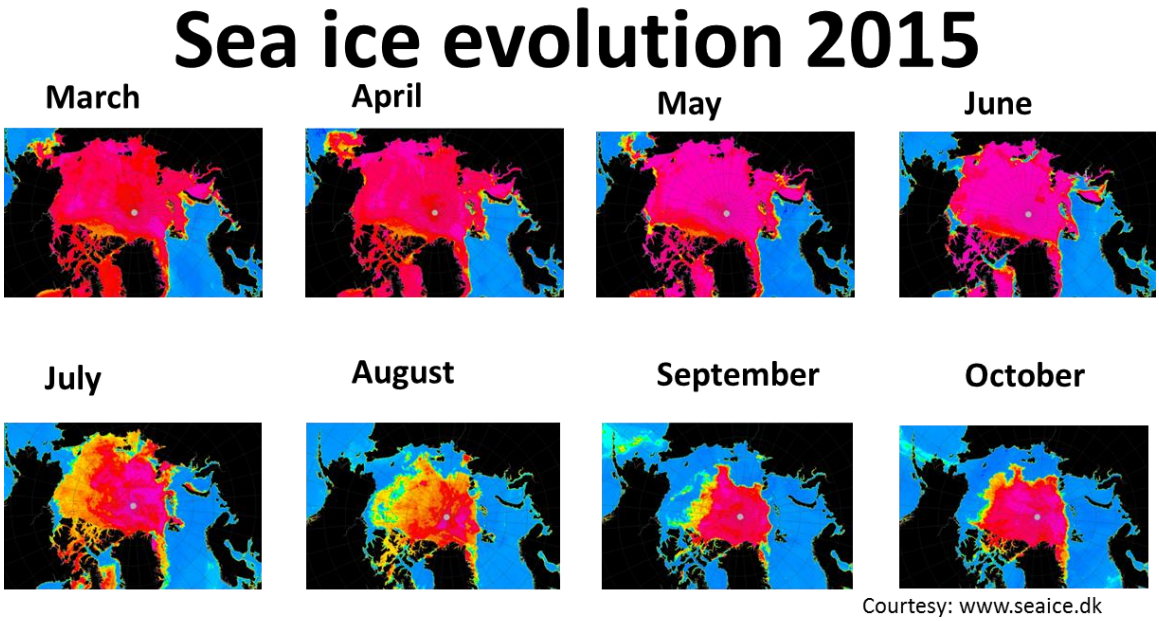
- 2 cm sensor spacing over 5 m
- hourly GPS
- hourly temperature
- 3 hourly heating/ice thickness
- 6 hr photograph
- Engineering data

2. **Logistics/Deployment:** The team contributed to the Summer cruise of *Araon*. BAS and SAMS were closely involved with science, logistic plans, health and safety, instrument deployment operations, as well as our communication and flight schedules. Through Hwang's close ties with KOPRI he was able to brief and advise the implementation of Supplementary MIZ activities during the Summer 2015 cruise of the *Araon*.

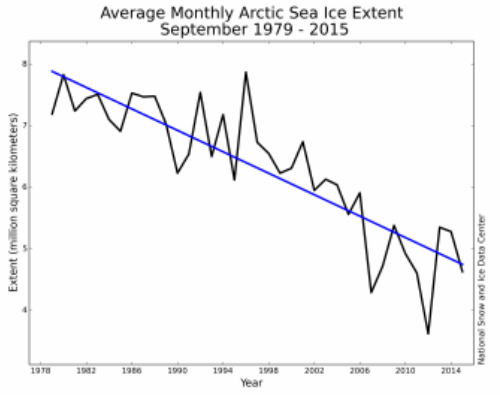
2015 review of the sea ice season.

According to NSIDC the daily minimum in 2015 occurred on September 11th, when the sea ice extent occupied 4.41 million square kilometres. This was the 4th lowest ice extent since satellite records began over 30 years ago.

From the ice concentration maps below we can see that the region north of Alaska/Canada started to open up in June and continued to open in to July. During August the ice edge moved away from the Alaskan coast and this northward movement of the ice edge continued into September. In October freeze up well underway and the ice edge began to move southward at all latitudes.



Courtesy: www.seaice.dk



Average monthly sea ice extent 1979 - 2015

Images courtesy of NISDC

Results/Analysis

On the 9th August 2015 (around 13:00 Alaskan time) the first of the WB/IMB pairs were deployed by Dr Phil Hwang from the Korean Icebreaker *Araon*. The camera from the WB221 and the camera on IMB12 were deployed facing each other. By doing so we were able to check the environment around each system, i.e.the loss of IMB10 (see pictures below)

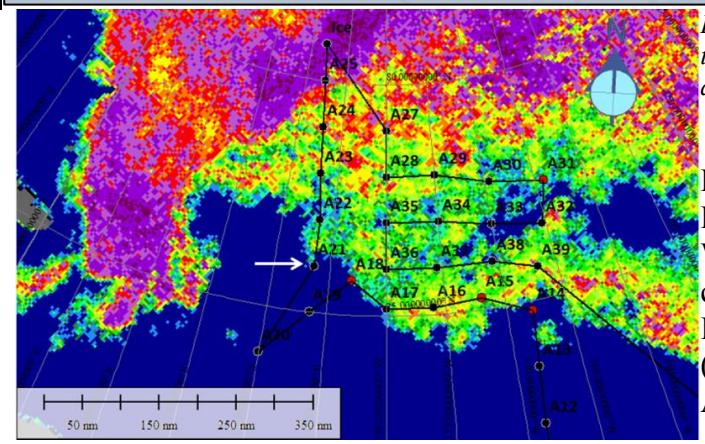
Image of WB221 as seen by IMB10, on the day of deployment

Image of IMB10 as seen by WB221, on the day of deployment

Strong winds and snow on 29 August mask WB221 in this photo.

This is the last image (29 August) of IMB10 before floe break up and the eventual loss of this IMB.

The next deployment of the WB/IMB pair (WB222/IMB009) on midnight of the 10th August was not successful. Upon deployment it was realised that we had a technical problem with WB222. This in itself should not have been a showstopper as we have the third wavebuoy, WB223, available. WB223 was brought out on to the ice and booted up. However this too had a similar technical issue which ruled out its deployment. Over the next few days a significant amount of time was put in to solving this problem, however an adequate solution was not found and therefore it was decided to not go forward with the deployment of the remaining systems (2 x WB, 2 x IMB and 1 x AWS). These systems will be deployed next year. The possible reasons behind these malfunctions are explained in the section below entitled System Diagnostics.



Deployment location of MIZ IMB/WB at the ice edge (left). Photo of IMB/WB deployed at the site (above).

During Summer Araon cruise, Hwang deployed 1x IMB and 1x WB (this work), and assisted with collaborative deployments of 3x IMBs (ICE-ARC), 10x Ice Drifters (KOPRI), and 1x SATICE (ICE-ARC).

System Diagnostics

It is extremely unusual for two systems to fail in identical ways, such as WB222 and WB223, especially as they were working correctly when the left the UK. We designed the systems to go through a number of test sequences upon boot up. Each test sequence is associated with a certain flash frequency of the camera LED. This process is to give the deployment team confidence that all is in order with the system when it is booted up and deployed. Our problem is that each WB signalled a 4-second LED flash. This error means that the WB cannot communicate to the modem AND it cannot communicate to the GPS. Interestingly each of these systems are located on separate serial devices and with separate serial ports. GPS is connected directly to the FOX motherboard via the wavebuoy board, and the Modem is also connected to the FOX board again via the wavebuoy board. Consequently this problem could be due to one of three issues:

1) a microprocessor/wavebuoy board problem
2) An SD card problem: The SD card has the operating system on it
3) Modem/cabling issues (unlikely)

We sent detailed diagnostic instructions to Phil Hwang on the *Araon* and they went through a thorough test/replace procedure. The outcome of which was that the SD card and operating system were working correctly, as were the modem and cables. Therefore the likely culprit was the FOX microprocessor board. This is off-the-shelf unit and not an easy fix.

We have now shipped the systems (2 x WB, 2 x IMB and 1 x AWS) to UAF for storage. The WBs will be fixed in late 2015 or early in 2016. The systems will be ready for deployment in summer of 2016 by *Araon*. Whilst this is extremely disappointing news there is a positive side. This is that the 2016 deployment will enable us to have a third year of wave measurements in the region.

1. Wave Analysis:

Of the three Wavebuoys that were built for the 2015 deployment only one was deployed. A summary of its deployment history can be seen in the following table.

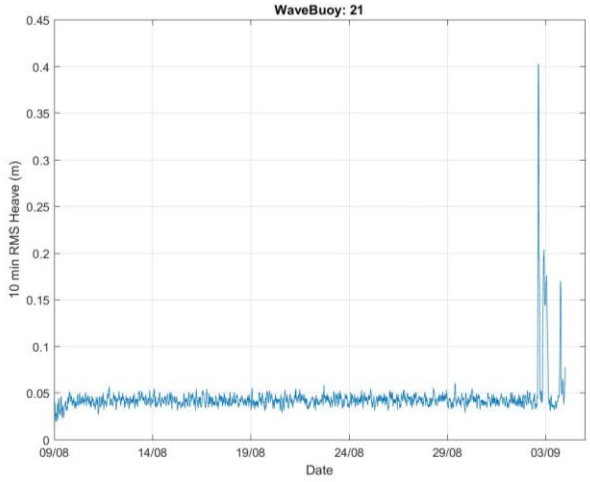
Wave Buoy identifier	Cluster / asset deployed with	Date of Deployment	Date of last data download	Number of days active
WB221	IMB10	2015-08-09	2015-09-04	26
WB222	IMB09	2016	N/A	N/A
WB223	IMB08/AWS06	2016	N/A	N/A

Table: Wavebuoy metrics by identification number.

The buoy, WB221, lasted for 26 days before its catastrophic failure. From the photographic evidence it looks like the system was caught and then squashed between ice floes, at this stage the buoy had broken free on the sea ice and was free floating. The last image it sent back can be seen below. This suggests the WB is pressed up besides the side of an ice floe.

Last image sent back by WB221.

As with the 2014 deployments limited wave activity was seen before the end of August. In early September two wave events were seen by WB221 (see RMS heave figure below). These wave events are probably part of the same weather system that halted Shell's drilling activity in the Chukchi Sea. It will be interesting to compare these wave measurements to those made by Shell (if available).



RMS of wave height (heave) for WB221. Each point in the graph is calculated from a 10 minute window of 1 second heave readings.

News article about the Arctic storm that halted Shell's Arctic drilling activity.

2. AWS Analysis

The AWS was not deployed in 2015. It will now be deployed in 2016.

3. IMB Analysis:

IMB10 was deployed on a thick ice floe. Its characteristics were:

- Ice thickness at the site: 376cm
- Freeboard: 16.0 cm
- Snow: 8.0 cm

The system worked until a large storm at the end of August broke the floe it was deployed upon. This can be seen below

Wave Buoy Identifier	Cluster / asset deployed with	Date of Deployment	Last data download (GPS /Chain data)	Days of activity (GPS /Chain data)
IMB10	WB221	2015-08-09	2015-09-05 / 2014-08-29	27/ 20
IMB09	WB223	2016	N/A	N/A
IMB08	WB223/AWS06	2016	N/A	N/A

Sitting nicely…

Storm hits…

Floe breaks apart, IMB in water, chain severed.

IMB incorporated in ridge….Dead

Even though the system only survived a limited period of time it provided significant information on the warming temperature profile of the ice. Warm sea ice has a significant higher brine volume and therefore is much weaker and then can break apart under the stress of wave energy.

5. Next Steps:

A team from BAS will go to UAF to fix the problematic WBs. These buoys, along with the IMBs and AWS, will now be released in the summer of 2016. The 2015 data presently being quality controlled.

IMPACT/APPLICATIONS
[Potential future impact for science and/or systems applications]
N/A at present.

TRANSITIONS
N/A at present.

RELATED PROJECTS
- ICE-ARC EU FP7 funded programme
- DRI-Sea State

REFERENCES
N/A

PUBLICATIONS
N/A

PATENTS
N/A

HONORS/AWARDS/PRIZES
N/A